USAARL Report No. 2003-08

The Role of the Pilots Night Vision System (PNVS) and Integrated Helmet and Display Sighting System (IHADSS) in AH-64 Apache Accidents

by Clarence E. Rash, Barbara S. Reynolds, Jessica A. Stelle, Robert D. Peterson, and Patricia A. Leduc

Aircrew Health and Performance Division

April 2003

USAARL

U.S. Army
Aeromedical Research
Laboratory

Notice

Qualified requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), 8725 John J Kingman Road, Suite 0944, Fort Belvoir, Virginia 22060-6218. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release, distribution unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAARL Report No. 2003-08	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Aeromedical Research Laboratory 6b. OFFICE SYMBOL *(If applicable)* MCMR-UAD	7a. NAME OF MONITORING ORGANIZATION U.S. Army Medical Research and Materiel Command
6c. ADDRESS *(City, State, and ZIP Code)* P.O. Box 620577 Fort Rucker, AL 36362-0577	7b. ADDRESS *(City, State, and ZIP Code)* 504 Scott Street Fort Detrick, MD 21702-5012
8a. NAME OF FUNDING / SPONSORING ORGANIZATION 8b. OFFICE SYMBOL *(If applicable)*	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS *(City, State, and ZIP Code)*	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
622787	879	P	DA336445

11. TITLE *(Include Security Classification)*
(U) The role of the pilots night vision system (PNVS) and integrated helmet and display sighting system (IHADSS) in AH-64 Apache accidents

12. PERSONAL AUTHOR(S)
C.E. Rash, B.S. Reynolds, J.A. Stelle, R.D. Peterson, and P.A. Leduc

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
Final	FROM TO	2003 April	25

16. SUPPLEMENTAL NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
helmet-mounted display (HMD), AH-64 accidents, Integrated Helmet and Display Sighting System (IHADSS), PNVS, FLIR

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*
Helmet-mounted displays (HMDs), while not new, are a unique method of providing pilotage and targeting imagery to aviators. Although there are a number of HMDs in various phases of design, the AH-64s Integrated Helmet and Display Sighting System (IHADSS) is currently the Army's only fielded integrated HMD. A number of studies have investigated the visual and perceptual issues associated with the monocular optical design of the IHADSS in combination with the AH-64s forward looking infrared (FLIR) thermal sensor (Pilots Night Vision System - PNVS). While these systems have greatly enhanced the operational effectiveness of the AH-64, they have resulted in reports of physiological complaints, degraded visual cues, and both static and dynamic illusions. This study investigated the possible role the IHADSS HMD and PNVS may have played in AH-64 Apache accidents. A total of 217 AH-64 accidents (FY85-02) were analyzed and assigned causal factors associated with the use of the IHADSS and PNVS. The resulting analysis failed to identify any significant role between these systems and flight-related accidents.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Supervisor, Science Information Center	22b. TELEPHONE *(Include Area Code)* (334) 255-6907 22c. OFFICE SYMBOL MCMR-UAX-SI

Acknowledgements

The authors with to thank the following individuals for contributions to this paper: 1LT Steven D. Morrow; CW4 Alan Ruzicka, Advanced Attack Armament Division Fort Eustis, VA; Art Estrada, USAARL; Sharon D. Manning, Aviation Branch Safety Office, Fort Rucker, AL; and CW5 William Rhode, U.S. Army Safety Center, Fort Rucker, AL.

Table of contents

Page

Introduction 1

Background 2

Accident database 8

Accident cause categorization 9

Analysis of accidents 13

Discussion and conclusions 18

Recommendations 20

References 21

Appendix. Summary of selected AH-64 accidents 23

List of figures

1. The AH-64D Apache helicopter 1

2. The Integrated Helmet and Display Sighting System (IHADSS) 1

3. Cockpit views of the AH-64A and AH-64D 2

4. The PNVS and TADS nose-mounted FLIR sensors on the AH-64 2

5. Two views of the IHADSS helmet display unit (HDU) 3

List of tables

1. Reports of degraded visual cues 4

2. Reports of static illusions 4

3. Reports of dynamic illusions 4

4. Miscellaneous reports 5

Table of contents (continued)
List of tables (continued)

Page

5. Percentage of aviators reporting visual problems during and after AH-64 flight................ 6

6. Reported vision complaints for 2000 IHADSS survey... 7

7. Descriptions of accident classes... 8

8. Summary of accident frequencies by accident class and fiscal year for the AH-64A and AH-64D model aircraft 10

9. Frequencies and relative percentages of all AH-64 flight accidents by attributed causal factor(s) 10

10. Frequencies and relative percentages of AH-64 flight accidents by associated causal factor(s) with HDU in use. 12

11. Summary of accident frequencies by accident class and fiscal year (FY85-FY02) for the AH-64 when HMD was in use 12

12. Summary of HMD in-use accidents by type. 13

13. Fault factors for accidents with types 1, 2 and 3. 13

14. Type 1 and 2 accidents fault factors 15

15. Summary of fault factors for accident types 1 and 2 17

Introduction

The AH-64 Apache is the U.S. Army's most advanced rotary-wing attack aircraft (Figure 1). It exists in two model configurations, the AH-64A and AH-64D. The AH-64D is referred to as having a "glass cockpit." This reference is made to the modified crewstation design employed in the AH-64D that replaces most of the traditional dedicated instruments with multifunction displays (MFDs). The D-model also has an expanded mission capability and may present a higher workload cockpit.

The AH-64 is flown using a helmet-mounted display (HMD) known as the Integrated Helmet and Display Sighting System (IHADSS) (Figure 2). This HMD presents pilotage imagery and flight symbology. Pilotage imagery originates from a nose-mounted forward-looking infrared (FLIR) sensor known as the Pilot's Night Vision System (PNVS). Several studies (Behar et al., 1990; Hale and Piccione, 1990; Crowley, 1991; Stewart, 1997; and Rash et al., 2002) have identified a number of visual problems and illusions that may be contributing factors to AH-64 accidents.

This study analyzed AH-64 accidents over the time period 1 October 1984 to 31 March 2002 (fiscal years [FYs] 85 to second quarter 02). The analysis focused primarily on accidents that can be attributed to flight with the IHADSS HMD and/or PNVS/FLIR imagery in the AH-64. Accidents associated with aircraft mechanical failure (other than relating to the FLIR or IHADSS) were tabulated but not analyzed.

Figure 1. The AH-64D Apache helicopter.

Figure 2. The Integrated Helmet and Display Sighting System (IHADSS).

The objective of this study was to investigate the possible role HMD and PNVS use may have played in AH-64 Apache accidents.

Background

The Army's AH-64 Apache attack helicopter uses a tandem-seating configuration. The dedicated instrument A-model was fielded in 1985. The glass cockpit D-model was introduced in 1997. The two cockpit designs are presented in Figure 3. The total flight hours for the AH-64A and AH-64D models (as of 31 March 2002) were 1,341,397 and 81,433, respectively.

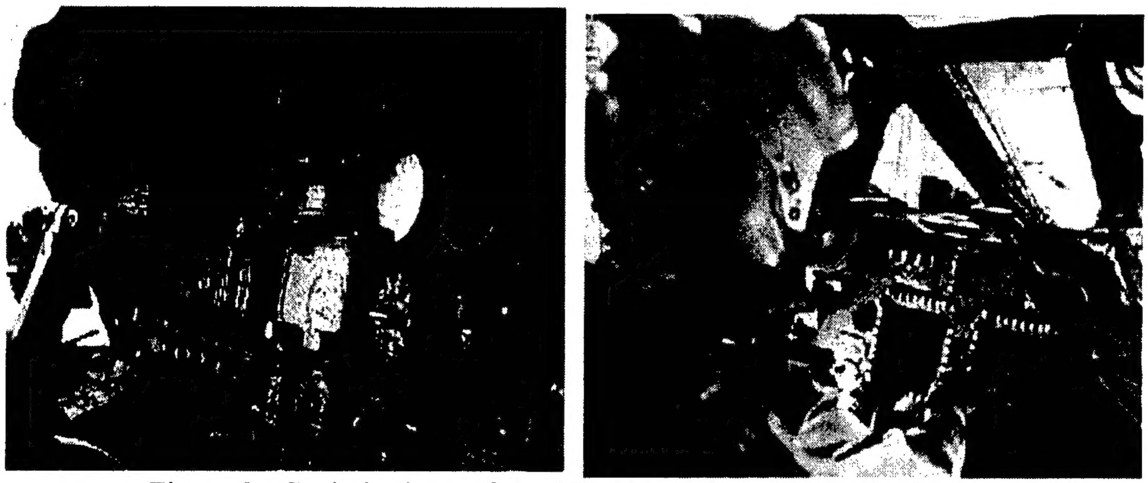

Figure 3. Cockpit views of the AH-64A (left) and AH-64D (right). (Pictures printed with permission from Boeing)

The AH-64 achieves its night and foul-weather capabilities through the use of two nose-mounted FLIR sensors (Figure 4). One is used for pilotage and one for targeting. The targeting FLIR sensor is known as the Target Acquisition and Designation System (TADS). The pilotage FLIR is the PNVS. Both FLIR sensors operate in the 8-12 micron spectral range.

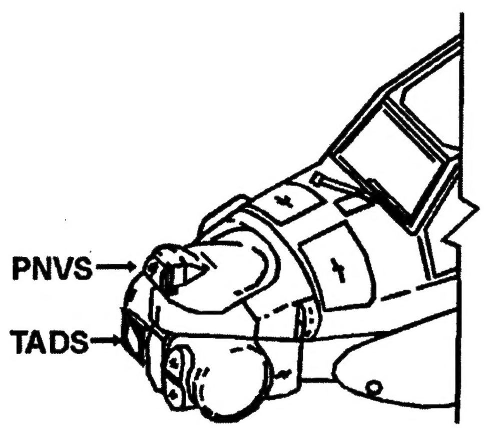

Figure 4. The PNVS and TADS nose-mounted FLIR sensors on the AH-64.

The FLIR imagery, along with aircraft status symbology, is displayed to the pilots via the AH-64's HMD, the IHADSS. The IHADSS consists of the helmet display unit (HDU) (Figure 5),

which is an optical relay unit incorporating a miniature 1-inch cathode ray tube (CRT). The HDU is mounted on the right side of the IHADSS helmet. Video imagery originating from the nose-mounted FLIR sensor is presented on the face of the CRT and is optically relayed and reflected off a beamsplitter (combiner) into the pilot's right eye. The presented imagery subtends a field of view (FOV) of 30 degrees vertically by 40 degrees horizontally. This imagery, presented to the right eye only, is what the pilot uses to fly and operate the AH-64 at night. The left eye is unaided, allowing the pilot to view cockpit displays and the outside world.

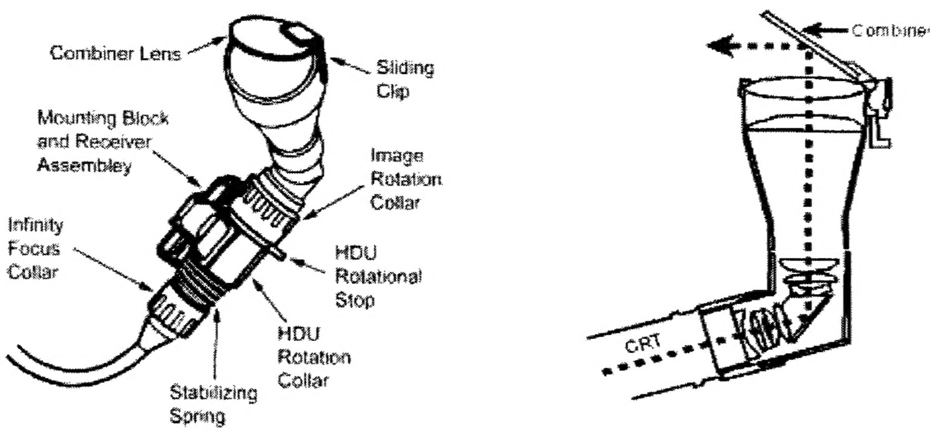

Figure 5. Two views of the IHADSS helmet display unit (HDU).

The AH-64 with its PNVS FLIR sensor and IHADSS HMD is a very challenging aircraft to fly. The pilot is expected to control and fly this tremendously sophisticated piece of machinery from a limited FOV (30 degrees vertical x 40 degrees horizontal) picture of the outside world that is a representation of the outside scene in a completely different spectral range (8-12 microns). Piloting and operating an aircraft in a military environment using an HMD places extraordinary demands on the human visual system. It is not unreasonable to suspect that this demanding visual and processing workload may contribute to, if not cause, accidents. This is an increasingly important issue with the increased use of HMDs in the rotary-wing cockpit.

During the early development of the IHADSS in the 1970s, considerable concern was voiced regarding the monocular design of the IHADSS. Visual issues such as the Pulfrich phenomena (apparent out of plane rotation of a moving target due to unequal binocular illumination), loss of stereopsis and depth perception, eye dominance, and binocular rivalry were the subjects of much discussion. In the late 1980s, numerous vision researchers intensified the concerns over the human visual system's response to viewing HMD virtual imagery and the possible impact on visual performance (Newman, 1987; Roscoe, 1987a,b; Weintraub, 1987). Between 1988 and 1990, three studies were conducted which seemed to confirm that pilots were experiencing some difficulties with flying the AH-64 using FLIR imagery presented on the IHADSS HMD.

In 1988, Hale and Piccione (1990) conducted an operational assessment of problems experienced with the IHADSS by the AH-64A pilot population. A survey questionnaire was distributed to 52 AH-64A pilots at Fort Hood, Texas. The questionnaire consisted of 37 items that addressed various human factor-engineering aspects of the PNVS and IHADSS systems. In

addition to the written questionnaire, verbal discussions were held with each pilot. The major areas of interest in the survey were: Perceptual inaccuracies, FLIR image quality, symbology, monocular viewing, spatial disorientation, and physical comfort. Based on pilot responses, FLIR quality, distance and size perception, ability to alternate attention between eyes, unintentional alternation, and limited FOV were the major concerns reported.

About the same time, in 1989, Crowley (1991) surveyed 242 aviators flying either the Aviator's Night Vision Imaging System (ANVIS), an image intensification device, or the Apache IHADSS soliciting reports of visual illusions during flight. Twenty-one (9%) of the respondents were Apache aviators reporting illusions or other visual effects with the FLIR sensor and IHADSS. The reports from the questionnaires were classified as either reports of degraded visual cues, static illusions, dynamic illusions, or miscellaneous reports. The most common degraded visual cue was impaired acuity (14%), i.e., degraded resolution/insufficient detail; the most common static illusion was that of faulty height judgment (19%); the most common dynamic illusions were undetected aircraft drift (24%) and illusory aircraft drift (24%), followed by disorientation (14%) and faulty closure judgment (10%); and the most common miscellaneous report was distracting symbology. Summaries of reports are presented in Tables 1 through 4.

Table 1.
Reports of degraded visual cues (n=21).
(Crowley, 1991)

Report	%	(n)
Degraded resolution/ insufficient detail	14	(3)
Loss of visual contact with horizon	10	(2)
Impaired depth perception	10	(2)
Decreased field of view	10	(2)
Inadvertent instrument meteorological condition (IMC)	5	(1)

Table 2.
Reports of static illusions (n=21).
(Crowley, 1991)

Report	%	(n)
Faulty height judgment	19	(4)
Trouble with lights	5	(1)

Table 3.
Reports of dynamic illusions (n=21).
(Crowley, 1991)

Report	%	(n)
Undetected aircraft drift	24	(5)
Illusory aircraft drift	24	(5)
Disorientation ("vertigo")	14	(3)
Faulty closure judgment	10	(2)

Table 4.
Miscellaneous reports (n=21).
(Crowley, 1991)

Report	%	(n)
Hardware-related problems Distracting symbology	14	(3)
Crew coordination problems Mixing FLIR and image Intensification	5	(1)
Physiological effects Dark adaptation effects	5	(1)

In summary, the questionnaire responses, although based on a very limited sample size (n=21), provided additional evidence that at least some Apache aviators flying with the FLIR sensor and IHADSS HMD were experiencing visual problems and illusions which were possibly degrading mission performance.

Prompted by the above studies and anecdotal complaints to Army flight surgeons, Behar et al. (1990) conducted a three-part study to investigate possible long-term vision effects of using the IHADSS monocular HMD. The first part of the study was a written questionnaire that served the purpose of documenting visual problems experienced by the local Fort Rucker, Alabama, Apache aviator training community (58 instructor pilots). The second part was a clinical and laboratory evaluation of the refractive and visual status of a sample of these aviators. The third part was an assessment of the diopter focus setting used by a random sampling of aviators in the field environment.

For the 58 Apache aviator questionnaires, 80 percent of the respondents reported at least one visual complaint experienced either *during* or *after* flight with the IHADSS. A summary of complaints is provided in Table 5. The most common complaint *during* flight was "visual discomfort." Over one-third of the respondents complained of experiencing headaches at least sometimes *after* flight.

In spite of the visual complaints reported in the questionnaires, the clinical and laboratory evaluation of 10 Apaches aviators found no statistical correlation between visual performance and visual complaints. In addition, there were no significant differences found between left and right eye performance. In summary, the study concluded that there were no significant deviations from normal visual performance on all the tests.

A possible explanation of some of the visual complaints was found in the diopter setting section of the study. This section measured the focus settings of 20 Apache aviators (11 student and 9 instructor pilots) following their preparation for flight. Nine were measured under nighttime illumination conditions and 10 under daytime conditions. A range in focus settings of 0 to -5.25 diopters (mean of -2.28 diopters) was obtained. It was concluded that the required positive accommodation by the eye to offset the negative focus settings was a likely source of

Table 5.
Percentage of aviators reporting visual symptoms *during* and *after* Apache flight.
(Behar et al., 1990)

	During flight (%)			*After* flight (%)		
	Never	Sometimes	Always	Never	Sometimes	Always
Visual discomfort	49	51	--	70	28	2
Headache	65	35	--	67	32	2
Double vision	86	12	2	89	9	2
Blurred vision	79	21	--	72	24	3
Disorientation	81	19	--	95	5	--
Afterimages	NA	NA	NA	79	19	2

headaches and visual complaints reported during and after prolonged flights. No correlation was found between the focus settings and aviator age or experience; nor were there differences between instructor and student pilots, or day versus night.

The survey in the Behar et al. study (1990) was limited in sample size (n = 58) and included only instructor pilots. In 2000, this basic survey was repeated for a much larger sample size (n = 216) and wider range of Apache experience (Rash et al., 2002). The year 2000 survey was a near complete duplication of the original 1990 survey and the Crowley 1989 visual illusion questionnaire combined, with added sections to inquire about helmet fitting and acoustic issues. This duplication allowed subjective comparison between aviator visual complaints and illusions across the 10-year period. In addition to the limited scope of the 1990 study, the new survey was desirable for the following reasons: (1) there was renewed interest in the presence of visual complaints with use of the monocular IHADSS, fueled by expanded fielding of the AH-64 Apache helicopter in the United Kingdom and other countries; and (2) during this period, the flight track for AH-64 aviators had changed. During the early years of the AH-64 fielding, all AH-64 aviators were experienced aviators who had transitioned from other aircraft (primarily the AH-1 Cobra). Since 1986, AH-64 aviators began transitioning directly from initial entry rotary-wing (IERW) training into flying the AH-64 Apache. And, as mentioned earlier, the respondents in the 1990 study were all experienced instructor pilots. The 2000 study included aviators with as few as 20 AH-64 flight hours.

The 2000 survey verified the continuing presence of visual problems for some Apache aviators. A summary of reported visual complaints is presented in Table 6.

The pertinent major conclusions from the newer survey were:

- There were sufficient data to indicate that responding Apache aviators flying with the IHADSS experience a relatively high frequency of a variety of visual symptoms; 92% of respondents reported at least one visual complaint/symptom either *during* or *after* flight.

Table 6.
Reported vision complaints for 2000 IHADSS survey.
(expressed in percent)

	During flight				After flight			
	Never	Sometimes	Always	NR	Never	Sometimes	Always	NR
Visual discomfort	18.5	76.4	5.1	0.0	25.5	66.2	7.9	0.5
Headache	38.9	59.7	0.9	0.5	36.1	61.1	1.4	1.4
Double vision	93.5	6.0	0.5	0.0	93.1	4.6	0.5	1.9
Blurred vision	66.2	33.3	0.5	0.0	63.0	36.6	0.5	0.0
Disorientation	57.4	42.1	0.0	0.5	88.4	9.7	0.0	1.9
Afterimages	70.4	27.3	1.9	0.5	51.9	41.7	5.1	1.4

- A comparison between findings in this survey and a similar one performed in 1990 showed subjective trend increases in the proportion of multiple visual symptoms to include visual discomfort and headaches both *during* and *after* flight with the IHADSS, for disorientation *during* flight, and for afterimages *after* flight.

- The frequency of complaints was not correlated to age or AH-64 flight experience.

- The data did not support any association between eye preference (dominant eye) and the number of complaints or the presence of unintentional alternation (switching) between the left, unaided eye and the right, aided eye viewing the IHADSS imagery.

- The two most reported static illusions were faulty slope estimation and faulty height judgment, reported by approximately three-quarters of the respondents. There was a high incidence of dynamic illusions reported, with six of the eight identified dynamic illusions reported by more than half of the respondents. The two most reported dynamic illusions were undetected drift and faulty closure judgment, reported by more than three-quarters of the respondents.

- When asked to provide additional comments, the single issue most strongly voiced by AH-64 aviators was the poor performance of the FLIR sensor. This survey does not allow the determination of what poor FLIR imagery contributes to the reported visual symptoms.

The background discussion above suggests that there may be some correlation between AH-64 accidents and the use of the PNVS sensor and IHADSS HMD.

This study has as its primary objective the investigation of the possible role that the IHADSS HMD and PNVS may have played in AH-64 accidents. This includes the incidence of HMD induced visual symptoms, e.g., headache, blurred vision, double vision, etc, and the incidence of HMD and PNVS induced static and dynamic illusions, e.g., faulty height judgment, faulty distance estimation, etc.

Accident database

The data analyzed herein were obtained from a search of the U.S. Army Risk Management Information System (RMIS) that was created in 1972 and is maintained by the U.S. Army Safety Center (USASC), Fort Rucker, Alabama. The USASC tracks three types of aviation accidents: flight, flight-related and ground. A flight accident is one in which intent for flight exists and there is reportable damage to the aircraft itself. Intent for flight begins when aircraft power is applied, or brakes released, to move the aircraft under its own power with an authorized crew. Intent for flight ends when the aircraft is at full stop and power is completely reduced. Flight-related and ground accidents are not used by the USASC in calculations of accident rates. The rates reported herein adopt these criteria and include flight accidents only. Accident rates are based on the number of occurrences per 100,000 flight hours and provided per FY (1 October through 30 September). Accident frequencies and rates used in this paper cover the period FY85-FY02 (first half, based on data entries made by 31 March 2002).

Army aviation accidents are classified as Class A, Class B, Class C, Class D, or Class E (Department of the Army, 1994). For the purposes of this study, Class D and Class E accidents are not included due to the large number and innocuous nature of these accidents with respect to aviation safety. A description of the criteria for Class A through C accidents used in this analysis is presented below (Table 7). Accident class criteria have been revised three times since 1972. The most recent revision was that of 1 October 2001 (FY02).

A summary of all AH-64 accidents, by accident class, as listed by the USASC database is presented in Table 8. There were a total of 217 AH-64A and 11 AH-64D Class A-C accidents for the period FY85 through the first half of FY02 (31 March 2002).

Table 7
Descriptions of accident classes.

Accident Class	FY 2002	Prior to FY 2002
A	Damage costs of $1,000,000 or more and/or destruction of an Army aircraft, missile or spacecraft and/or fatality or permanent total disability	Damage costs of $1,000,000 or more and/or destruction of an Army aircraft, missile or spacecraft and/or fatality or permanent total disability
B	Damage costs of $200,000 or more, but less than $1,000,000 and/or permanent partial disability and/or three or more people are hospitalized as inpatients	Damage costs of $200,000 or more, but less than $1,000,000 and/or permanent partial disability and/or five or more people are hospitalized as inpatients
C	Damage costs of $20,000 or more, but less than $200,000 and/or non-fatal injury resulting in loss of time from work beyond day/shift when injury occurred and/or non-fatal illness/disability causes loss of time from work	Damage costs of $10,000 or more, but less than $200,000 and/or non-fatal injury resulting in loss of time from work beyond day/shift when injury occurred and/or non-fatal illness/disability causes loss of time from work

Note: Accident class criteria have been revised three times since 1972. The most recent revision [1 October 2001 (FY02)] has occurred since data for this paper were collected. Data analyzed in this paper have been classified according to the above criteria (Table 7).

The objective of this investigation was to look at the role that the IHADSS HMD and the PNVS/FLIR may have played in past AH-64 Apache accidents. Therefore, each accident (record) was scrutinized with respect to HMD use and/or PNVS/FLIR image quality influence.

Accident cause categorization

The RMIS database assigns each accident a primary cause in regards to contributing factors. These causal factors are: Human error, materiel failure, and environment. An accident may be assigned more than one causal factor. A human error accident is defined as an accident where job performance, which differs from that which is normally required in a situation, caused or contributed to the accident. An example of a human factor error would be where an aircrew member inadvertently activated the chop switch during flight, causing the engines to idle. Environmental factors include conditions such as noise, illumination, bird strikes, and space and weather conditions that have an adverse effect on the performance of the individual or equipment, which causes or contributes to the accident. Materiel failure is when equipment: a) stopped working entirely, b) worked, but malfunctioned, or c) has degraded to the point that machinery was unreliable/unsafe_for continued use. Examples of this type of failure would be an engine overheating or main rotor revolutions-per-minute (RPM) decay.

Table 9 shows the frequencies and percentages for the USASC attributed causal factors for <u>all</u> AH-64A and AH-64D accidents from FY85 through first half of FY02 (31 March 2002). A review of Table 9 shows that the accidents were dominated by the "human error" causal factor, both alone and in combination with one of the other cause factors (66.3% for the AH-64A and 36.4% for the AH-64D. This observation is in agreement with a 1998 3-year review (FY95-97) of the safety performance of the AH-64, which concluded that human performance error was the primary causal factor for that period (McGee, 1998). The study raised the question of the possible role of task saturation as a contributing factor. This was not a surprising possibility since, in addition to physically maneuvering around obstacles both on and off the ground, the aviator must pay close attention to numerous other sources of information such as from panel-mounted cockpit displays, the HMD, and audio/communication systems. Having to interpret pilotage and gunnery data from the cockpit displays or the HMD easily could contribute to task overload.

For the purpose of this investigation, the causal factors used by the USASC were too broad and could not provide insight into the role of HMD and PNVS use in each accident. Therefore, each AH-64A/D accident was reviewed and assigned to one of five types using a scheme developed for spatial orientation accident analysis by Durnford et al. (1995). These types were defined as follows:

- Type 1. HMD and/or PNVS use was the major component of the accident sequence (which meant that all other contributory factors normally would have been overcome without mishap).

Table 8.
Summary of accident frequencies by accident class
and fiscal year for the AH-64A and AH-64D model aircraft (FY85-FY02*)

	AH-64A flight accidents				AH-64D flight accidents			
	Class A	Class B	Class C	Classes A – C	Class A	Class B	Class C	Classes A – C
FY85	0	1	1	2	-	-	-	-
FY86	3	0	2	5	-	-	-	-
FY87	4	1	4	9	-	-	-	-
FY88	0	1	5	6	-	-	-	-
FY89	4	2	7	13	-	-	-	-
FY90	3	2	3	8	-	-	-	-
FY91	6	4	9	19	-	-	-	-
FY92	5	2	6	13	-	-	-	-
FY93	5	4	8	17	-	-	-	-
FY94	4	1	12	17	-	-	-	-
FY95	2	2	8	12	-	-	-	-
FY96	3	2	8	13	-	-	-	-
FY97	3	0	11	14	0	0	0	0
FY98	3	0	15	18	0	0	0	0
FY99	4	1	16	21	2	2	2	6
FY00	1	0	11	12	0	0	0	0
FY01	0	5	7	12	0	0	2	2
FY02*	2	2	2	6	0	0	3	3
TOTALS	**52**	**30**	**135**	**217**	**2**	**2**	**7**	**11**

*Note: The data shown represent class A-C flight accidents through the first half of FY02 (31 March 2002) only.

Table 9.
Frequencies and relative percentages of
all AH-64 flight accidents by attributed causal factor(s)

	AH-64A		AH-64D	
Causal factor(s)	Frequency	Percent	Frequency	Percent
Human error	123	56.7	3	27.3
Materiel failure	42	19.4	2	18.2
Environmental	6	2.8	0	0
Human error and materiel failure	17	7.8	1	9.1
Human error and environmental	4	1.8	0	0
Materiel failure and environmental	1	0.5	0	0
Human error, materiel failure and environmental	0	0	0	0
Not classified	24	11.1	5	45.5
Total	217	100.0	11	100.0

- Type 2. HMD and/or PNVS use was a subsidiary component of the accident sequence (which meant that other contributory factors would have led to a mishap in any case, but HMD and/or PNVS use made the accident sequence more difficult to deal with or the outcome more severe).

- Type 3. HMD and/or /PNVS use was an incidental component (which meant that HMD and/or PNVS was used or was present but did not affect the outcome).

- Type 4. HMD and/or PNVS not in use.

- Type 5. HMD and/or PNVS use was unknown.

Type assignment was a measure of the indicated strength of contribution of HMD and/or PNVS use to the accident. The minimum standard for assigning a given accident to one of the above types was not, in all cases, one of absolute certainty but was one based on the opinions and views of the authors and subject matter experts. It is important to note that during the early fielding of the AH-64 Apache, there was an insufficient awareness on the part of accident investigation teams of the impact of the novel monocular IHADSS HMD design on aviator visual performance, situational awareness, etc.

After applying type assignment to all Apache accidents, there were a total of 93 AH-64A and 4 AH-64D accidents for the period FY85 through the first half of FY02 (31 March 2002) for Class A-C accidents for which the HMD/PNVS was identified as in use (Types 1-3). There were 33 AH-64A and 5 AH-64D accidents in which use or nonuse of the HMD/PNVS was not recorded (Type 5). A thorough review of these unidentified accidents revealed that one AH-64A Class C accident should have been identified as an HMD/PNVS in-use accident. Therefore, the total number of HMD/PNVS in-use accidents analyzed in this study was 94 AH-64A and 4 AH-64D. The accident frequencies and associated percentages by USASC causal factors for these 98 accidents are presented in Table 10. For the AH-64A, the trend for the majority of accidents to be categorized as "human error" was maintained. Human error was found to contribute to 79.8% of AH-64A and 50% of AH-64D accidents where the HDU was in use. However, with only 4 AH-64D accidents to review, it would be inappropriate to generalize the AH-64D finding to the general population.

Types 4 and 5 accidents, in which the IHADSS HMD/PNVS was clearly indicated as not in use or use was unknown, were eliminated. The remaining accidents, those where HMD/PNVS use was indicated, are summarized by aircraft model and fiscal year in Table 11 and by type and aircraft model in Table 12.

Table 10.
Frequencies and relative percentages of AH-64 flight accidents by associated causal factor(s) with HDU in use.

	AH-64A		AH-64D	
Causal factor(s)	Frequency	Percent	Frequency	Percent
Human error	67	71.3	1	25.0
Materiel failure	7	7.4	0	0
Environmental	3	3.2	0	0
Human error and materiel failure	8	8.5	1	25.0
Human error and environmental	0	0	0	0
Materiel failure and environmental	0	0	0	0
Human error, materiel failure and environmental	0	0	0	0
None	9	9.6	2	50.0
Total	94	100.0	4	100.0

Table 11.
Summary of accident frequencies by accident class and fiscal year (FY85-FY02*) for the AH-64 when HMD was in use.

	AH-64A flight accidents				AH-64D flight accidents			
	Class A	Class B	Class C	Classes A – C	Class A	Class B	Class C	Classes A – C
FY85	0	0	0	0	-	-	-	-
FY86	1	0	1	2	-	-	-	-
FY87	1	0	3	4	-	-	-	-
FY88	0	0	3	3	-	-	-	-
FY89	2	1	5	8	-	-	-	-
FY90	1	0	2	3	-	-	-	-
FY91	4	3	3	10	-	-	-	-
FY92	0	0	3	3	-	-	-	-
FY93	4	2	0	6	-	-	-	-
FY94	2	0	5	7	-	-	-	-
FY95	2	2	1	5	-	-	-	-
FY96	3	0	2	5	-	-	-	-
FY97	1	0	4	5	0	0	0	0
FY98	2	0	5	7	0	0	0	0
FY99	3	1	10	14	1	1	0	2
FY00	1	0	4	5	0	0	0	0
FY01	0	1	3	4	0	0	2	2
FY02*	1	1	1	3	0	0	0	0
TOTALS	**27**	**11**	**55**	**94**	**1**	**1**	**2**	**4**

*Note: The data shown represent class A-C flight accidents for the period FY85 through the first half of FY02 (31 March 2002).

Table 12.
Summary of HMD in-use accidents by type.

	Type 1	Type 2	Type 3
AH-64A	2	19	3
AH-64D	0	0	74
Total	2 (2%)	19 (19%)	77 (79%)

Analysis of accidents

After categorized by type, those accidents where the HMD was identified as a major or subsidiary component of the accident sequence (Types 1 and 2) were analyzed for causal fault factors. Table 13 provides a list of six major fault factors used to further characterize these accidents. These major factors were a) display-related, b) degraded visual cues, c) static illusions, d) dynamic illusions, e) hardware problems related to PNVS/IHADSS, and f) crew coordination related to PNVS/IHADSS use. The following paragraphs briefly describe and provide an example(s) of each major fault factor.

Table 13.
Fault factors for accidents with Types 1, 2 and 3.

Accident fault factor
Display-related
Physiological causes
HDU impact on visual field/FOV
Alternation/rivalry
Degraded (insufficient) resolution
Degraded visual cues
Loss of visual contact with horizon
Impaired depth perception
Limited PNVS FOV
Inadvertent (IMC)
Static illusions
Faulty height judgment
Trouble with lights
Dynamic illusions
Undetected drift
Illusionary drift
Faulty closure judgment
Disorientation (vertigo)
Hardware problems related to PNVS/IHADSS
PNVS/FLIR sensor failure
IHADSS display/HDU failure
Design limitation
Crew coordination related to PNVS/IHADSS

Display-related factors were those that encompassed issues relating to the interpretation of the display information or interaction(s) between the pilot and the HDU display. Four sub factors were included as display related. These could be physiological, to include conditions such as diplopia (double vision), blurred vision, dark adaptation, etc. Another factor was the impact of the HDU fit and function on the available FOV. The factor of alternation (or rivalry) addressed situations where the pilot was either unable to optimally select between the two visual inputs or was subject to uncontrollable alternation of inputs. Degraded (insufficient) resolution referred to the failure of the display to provide the pilot with sufficient resolution to perform required tasks. However, a degraded display image also may have been caused by poor FLIR sensor operation or poor FLIR conditions (weather, time of day, etc.), factors that are addressed below.

Degraded visual cues were associated with situations or conditions where there was partial or total loss of visual information. These factors included loss of visual contact with the horizon, impaired depth perception, limited PNVS FOV, or the onset of inadvertent IMC resulting from poor FLIR conditions.

Static illusion factors were associated with situations or conditions that could have contributed to an accident by virtue of causing a misinterpretation or misjudgment of available information during activities where there was no relative motion (Rash, Verona and Crowley, 1990). These factors were faulty height judgment and trouble with lights.

Dynamic illusions were the misinterpretation or misjudgment of visual information due to relative motion (Rash, Verona and Crowley, 1990). These factors were undetected and illusionary drift, faulty closure judgment, and disorientation (vertigo).

Hardware-related factors addressed PNVS FLIR or IHADSS system failures or malfunctions. Examples included inadvertent release of HDU, FLIR or CRT display power supply failure, and FLIR gimbal lock-up. This category also encompassed design limitations of the PNVS FLIR, e.g., the PNVS sensor has a limited resolution defined by its thermal detector's D^* value (D-star, a measure of detectivity), which could have resulted in the inability of the detector to be able to discriminate between two objects having a very small temperature differential.

Crew coordination factors related to the PNVS/IHADSS systems were the final major category used to further differentiate accident causes. An example of this type of incident would be having both members of the crew focusing on FLIR imagery at the cost of neglecting duties related to flying.

The 21 accidents in which the HDU/PNVS were suspected to have played a role were evaluated by both U.S. Army Aeromedical Research Laboratory (USAARL) researchers as well as by an experienced Apache pilot (who served as a member of the accident investigation team for many of the accidents in this study). Summaries of accidents were studied and a worksheet was designed to standardize the issues examined in each accident (Table 14). [See Appendix for sample summaries of accidents]. Issues considered were display-related problems, degraded visual cues, illusions (both static and dynamic), hardware problems and crew coordination issues (Table 13). Readers are cautioned that many of these factors are not mutually exclusive, and assignment of factors, while by no means arbitrary, is open to discussion.

Table 14 .
Type 1 and 2 accident fault factors.

	Accident Identification Number									
	1	2	3	4	5	6	7	8	9	10
Accident Class	C	A	A	A	C	C	A	C	A	A
Type	2	2	2	2	2	2	1	2	2	2
Accident factor analysis										
Display related										
Physiological causes										
HDU impact on visual field			x							
Alternation/rivalry								X (Note 2)		
Degraded resolution	x									x
Degraded visual cues										
Poor FLIR conditions										x
Loss of visual contact with ground							x	x		
Impaired depth perception		x				x	x		x	
Limited PNVS FOV					x					
Inadvertent IMC			x				x			
Static illusions										
Faulty height judgment					x	x				
Trouble with lights										
Dynamic illusions										
Undetected drift	x		x	x	x	x	x			
Illusionary drift										
Faulty closure judgment						x	x		x	
Disorientation/vertigo				x			x	x		
Hardware related problems PNVS/IHADSS										
PNVS/FLIR sensor failure	x						x			x
IHADSS Display/HDU failure										
Design limitation		x			x				x	
Crew coordination related to PNVS/IHADSS										
Division of attention	x			x				x	x	x

NOTE 1: Accidents were identified by fiscal year of occurrence, using -1, -2 or -3 to indicate a series if more than one accident occurred during that period.
NOTE 2: The accident investigator suspected, but did not conclude, that this factor was present.

Table 14 (cont).
Type 1 and 2 accident fault factors.

	Accident Identification Number										
	11	12	13	14	15	16	17	18	19	20	21
Accident Class	B	C	A	B	B	A	A	C	C	B	C
Type	2	2	2	1	2	2	2	2	2	2	2
Accident factor analysis											
Display related											
Physiological causes											
HDU impact on visual field											
Alternation/rivalry											
Degraded resolution		x							x		x
Degraded visual cues											
Poor FLIR conditions		x		x			x				
Loss of visual contact with ground											
Impaired depth perception											
Limited PNVS FOV											
Inadvertent IMC											
Static illusions											
Faulty height judgment							x	x		x	
Trouble with lights											
Dynamic illusions											
Undetected drift	x	x		x	x				x		
Illusionary drift											
Faulty closure judgment					x		x				
Disorientation/vertigo											
Hardware related problems PNVS/IHADSS											
PNVS/FLIR sensor failure							x		x		
IHADSS Display/HDU failure											
Design limitation				x							x
Crew coordination related to PNVS/IHADSS											
Division of attention		x	x	x		x	x	x		x	

NOTE 1: Accidents were identified by fiscal year of occurrence, using -1, -2 or -3 to indicate a series if more than one accident occurred during that period.
NOTE 2: The accident investigator suspected, but did not conclude, that this factor was present.

A summary of the accident fault factors, as assigned in Table 14, is presented in Table 15. The leading factors identified were those related to dynamic illusions, degraded visual cues, and crew coordination. Dynamic illusions, which included undetected drift, faulty closure judgment, and disorientation, were associated with 91% (19 of 21) of the accidents. Of these dynamic illusions, undetected drift was singularly identified as the most common illusion, with 52% (11 of 21) of all accidents associated with this problem. The second most frequently found major causal factor was degraded visual cues, with it being associated with 62% (13 of 21) of the accidents. This was followed by the crew coordination factor found in 57% (12 of 21) of the accidents.

Table 15.
Summary of fault factors for accident types 1 and 2.

Accident Fault Factor	Number of accidents in which the factor was determined to be present/contributing	Totals by accident fault factor
Display-related		**7**
Physiological causes	0	
HDU impact on visual field	1	
Alternation/rivalry	1	
Degraded (insufficient) resolution	5	
Degraded visual cues		**13**
Poor FLIR conditions	4	
Loss of visual contact with ground	2	
Impaired depth perception	4	
Limited PNVS FOV	1	
Inadvertent IMC	2	
Static illusions		**5**
Faulty height judgment	5	
Trouble with lights	0	
Dynamic illusions		**19**
Undetected drift	11	
Illusionary drift	0	
Faulty closure judgment	5	
Disorientation (vertigo)	3	
Hardware-related problems PNVS/IHADSS		**10**
PNVS/FLIR sensor failure	5	
IHADSS display/HDU failure	0	
Design limitation	5	
Crew coordination related to PNVS/IHADSS	12	**12**

The remaining and less reported causal factors were hardware-related (48%), display-related (33%), and static illusions (24%). The most common hardware-related factor was associated with the PNVS FLIR sensor, degraded resolution was most common for display-related, and faulty height judgment was the sole static illusion.

Discussions and conclusions

The IHADSS used on the AH-64 Apache helicopter is a very unique system. While presenting a somewhat similar flight scenario to that of flying with image intensification-based night vision goggles, it differs in several ways. First, it is a monocular system, presenting the FLIR imagery only to the right eye. Second, the flight imagery is presented in a limited 30° x 40° FOV. Third, the perspective of this imagery is exocentric in location, since the FLIR sensor is located several feet forward and below the actual pilot eye position. And, lastly, the information content of the FLIR imagery is based on an entirely different part of the spectrum, 8-12 microns, than is normally presented to the human visual processing system. All of these factors result in the AH-64 pilot attempting to fly a sophisticated aircraft under very unusual conditions.

The investigation of any accident involves hundreds of factors, and it is a challenging task to attempt to keep up with the continuing and ever increasing change in technology in Army rotary-wing aircraft. For this reason, it is not always possible to identify and capture all of the important and necessary data needed to fully understand the impact and role of novel systems such as the IHADSS/FLIR system in accidents. Consequently, current accident data reporting forms do little more than record whether or not night vision devices, such as the IHADSS, were in use. Any additional, but pertinent data, must be sought, interpreted, analyzed, and recorded by accident investigators in an unstructured format. This often has resulted in insufficient data to fully characterize the role and impact of the IHADSS in AH-64 accidents. This is especially true regarding information that might be related to display image quality, degraded visual cues, and both static and dynamic illusions.

Of the 228 accidents reported during the time period FY85 to FY02 (through 31 March 2002), fewer than half (43%) of the AH-64 accidents (both A and D models) involved the use of the IHADSS HMD. Of all AH-64 accidents studied, only 9.2% (21 of 228) were categorized as ones in which the HMD and PNVS played a major or subsidiary role in the accident sequence itself. When only Type 1 accidents are considered, those in which the IHADSS/FLIR system was identified as the <u>major</u> contributor, they represented less than 1% of all AH-64 accidents and only 2% of accidents where IHADSS use was identified. While these were relatively small percentages, the 21 combined Type 1 and 2 accidents did represent 21% of the 98 accidents in which the IHADSS was identified as in use.

The most frequent causal factor in all of the accidents studied was dynamic illusions (91%), with undetected drift being the most common type. As an example, in accident 6, a Class C/Type 2 accident, the aircraft was allowed to drift into a tree because the student pilot failed to adequately monitor instruments, and the instructor pilot misjudged the position of the aircraft in relation to the trees (height judgment, 24%).

The second most frequent causal factor was degraded visual cues (62%), which was distributed across multiple sub factors with poor FLIR conditions (19%) and impaired depth perception (19%) being more common. This was exemplified in accident 14 (Class B/Type 1) where the crew was operating under poor FLIR conditions (following 4 days of rain). While trying to maintain a hover, the poor PNVS/FLIR visual cues, in conjunction with a lack of depth

perception, prevented the crew from detecting the presence of trees, and failing to detect aircraft drift, allowed the main rotor blades to make contact with the trees.

In 57% of the accidents, inadequate crew coordination was identified as a causal factor. For example, in accident 13 (Class A/Type 2), while transitioning from an air to a hover taxi, the pilot in command, unable to perceive ground references and determine altitude and drift, failed to request assistance from the pilot, who was troubleshooting the PNVS. Consequently, the aircraft hit the ground in an 85°-left yaw attitude. In August 2002, the USASC's aviation safety risk management magazine, Flightfax, published a review of the AH-64's safety performance for fiscal years 1998 through 2002 (as of 12 August 2002) (Lyle, 2002). In this review, failure in crew coordination was an often-cited contributing factor.

The presence and frequency of the above causal factors in the AH-64 accidents studied are consistent with the findings of Crowley (1991) and Rash et al. (2002). Both studies listed pilot-reported problems associated with dynamic illusions, particularly undetected drift. Poor sensor performance was also noted in Hale and Piccione's study (1990) and Rash et al. (2002). However, it is worth noting that the two most prevalent causal factors/sub factors were crew coordination and undetected drift, conditions not exclusive to the AH-64 Apache. Crew coordination is a frequent U.S. Army aviation safety topic of discussion (USASC, 2001). A review of the USASC database for the period FY99 through 1st quarter FY02 showed that a total of 13% Class A-C accidents involved crew coordination. The constant need to "tweak" the FLIR sensor output and its display was shown to contribute to the workload in the cockpit and often served as a distracter from other flight duties, a scenario which calls for increased crew coordination.

Some of the causal factors were directly tied to the AH-64 aircraft, and more specifically to the IHADSS/PNVS. Most of these instances were associated with the quality of the FLIR imagery. The most recent and extensive survey of visual problems and issues associated with the AH-64 HMD (Rash et al, 2002), found FLIR quality to be one of the strongest concerns among AH-64 pilots. Designed during the late 1970's, the AH-64's thermal sensor in combination with the IHADSS provides an equivalent Snellen visual acuity of only 20/60 (Green, 1988). It is hoped that the FLIR sensor upgrade planned for the near future comes to fruition.

In summary, while the presence and use of the IHADSS HMD present a very unique situation in the AH-64 Apache cockpit, it does not seem to be a major contributor to accidents. However, it does seem to serve as one more factor that increases workload and requires increased crew coordination. Of greater impact to safety is the inability of poor FLIR sensor performance to provide pilots with sufficient resolution. This poor performance is greatly increased during and following periods of environmental conditions that render the FLIR sensor ineffectual. The resulting lack of image quality significantly increases visual workload.

Recommendations

1. Create a supplemental accident form that provides a section for a pilot interview in which visual illusions and HMD physical problems experienced during flight could be captured. Included in this form should be any instances of visual symptoms that may be attributed to use of the IHADSS.

2. Ensure that the planned PNVS FLIR sensor upgrade, which will provide increased resolution and higher quality flight imagery, is implemented in a timely fashion.

3. Pilot workload while flying the AH-64 with HMD/PNVS systems should be evaluated and its impact on flight safety should be investigated further.

4. Increase command emphasis on crew coordination in the AH-64 cockpit.

References

Behar, I., Wiley, R. W., Levine, R. R., Rash, C. E., Walsh, D. J., and Corum, R. L. S. 1990. Visual survey of Apache aviators (VISAA). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 90-15.

Crowley, J. S. 1991. Human factors of night vision devices: Anecdotes from the field concerning visual illusions and other effects. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 91-15.

Department of the Army. 1999. Accident reporting and records. Washington, D.C. AR385-40.

Durnford, S. J., Crowley, J. S., Rosado, N. R., Harper, J., and DeRoche, S. 1995. Spatial disorientation: A survey of U.S. Army helicopter accidents 1987-1992. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 95-25.

Green, D. A. 1988. Night Vision Pilotage System field-of-view (FOV)/resolution tradeoff study flight experiment report. Fort Belvoir, VA., NV 1-26.

Hale, S., and Piccione, D. 1990. Pilot performance assessment of the AH-64A helmet display unit. U.S. Army Human Engineering Laboratory: Aberdeen proving Ground, MD. HEL TN 1-90.

Lyle, C. 2002. AH-64A safety performance review. Flightfax, Fort Rucker, AL: U.S. Safety Center. Vol. 30, No. 8.

McGee, M. 1998. AH-64A safety performance review. Flightfax, Fort Rucker, AL: U.S. Safety Center. Vol. 26, No. 11.

Newman, R. L. 1987. Response to Roscoe, The trouble with HUDs and HMDs. Human Factors Society Bulletin. 30(10), 3-5.

Rash, C. E., Verona, R. W., and Crowley, J. S. 1990. Human factors and safety considerations of night vision systems flight using thermal imaging systems. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 1990-10.

Rash, C. E., Suggs, C. L., Mora, J. C, Adam, G. E., van de Pol, C., and Reynolds, B. S. 2002. Visual issues survey of AH-64 Apache aviators (Year 2000). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 2002-02.

Roscoe, S. N. 1987a. The trouble with virtual images revisited. Human Factors Society Bulletin. 30 (11), 3-5.

Roscoe, S. N. 1987b. The trouble with HUDs and HMDs. Human Factors Society Bulletin. 30 (7), 1-3.

Stewart, J. E. 1997. The effects of the AH-64A Pilot's Night Vision System on the performance of seven simulated maneuver tasks. The International Journal of Aviation Psychology, 7(3), 183-200.

U.S. Army Safety Center. 2001. Aircrew coordination: Being too polite can get you killed. Flightfax, Fort Rucker, AL: U.S. Safety Center. Vol. 29, No. 7.

Weintraub, D. J. 1987. HUDs, HMDs, and common sense: Polishing virtual images. Human Factors Society Bulletin. 30 (10), 1-3.

Appendix.

Summaries of selected AH-64 accidents

Accident Identification Number	Class	Accident Summary
3	A	This night training accident occurred during a flight at low altitude. The aircraft crew encountered Instrument Meteorological Conditions (IMC). While reaching to locate and adjust the intensity of his instrument panel lights, the pilot removed his hand from the collective. He was also trying to remove the Helmet Display Unit (HDU) from in front of his eye, thereby allowing the aircraft to experience a gradual descent. The aircraft contacted the ground at 85 knots, rebounded into the air, finally coming to rest after rotating 180 degrees.
4	A	While hovering at night using the PNVS, the pilot inadvertently allowed the aircraft to drift rearward into a tree. An improper division of attention occurred on the part of the IP at the controls in trying to maintain aircraft controls while monitoring the movement of other aircraft and concerning himself with perceived anomalies in the aircraft's visual symbology. The pilot was also diverted, inputting data into the Doppler navigation system rather than assisting the IP with obstacle clearance. The IP had also not flown a Night Vision System (NVS) flight in the month previous and had become spatially disoriented in the field over the waving grass. Fatigue also played a role as both pilots had exceeded the allowed crew duty period for the past 48 hours. The flight video recording system was not turned on to record any malfunctions in flight and/or Forward Looking Infrared (FLIR) symbology as well as copilot and radio communications.
7	A	This accident involved an aircraft in NVS flight in low visibility conditions. The lead aircraft in a flight of four became disoriented after a lead change during rejoining with flight and lost visual reference to the ground after suspected PNVS failure. The aircraft impacted the ground at a high rate of speed, became airborne again, and landed with major structural damage on rocky terrain.
8	C	This night accident involved an aircraft conducting a night gunnery mission. The pilot allowed the copilot to make a 180-degree right hand descending turn to a hover, a critical flight maneuver, while occupied with the radios. The copilot lost reference of the flight symbology and the ground. The aircraft hit the ground level in a right lateral drift, bounced and then came to rest upright.

10	A	This accident occurred during a night annual aviator proficiency and readiness test. The IP misinterpreted the aircraft's response to the pilot's control inputs as a loss of tail rotor control. When the pilot's attempted recovery was unsuccessful, the IP took the controls with the aircraft in an unusual attitude, drifting toward the rear and with a right yaw. He misinterpreted this as a tail rotor malfunction and initiated anti-torque failure procedures. (The IP had only 18 hours of flight time as an IP with NVS). Severe aircraft vibration developed, causing the IP's HDU to move out of position and the pilot's HDU to fall off. The IP used the Visual Display Unit (VDU) symbology and lowered the collective to land. The aircraft made a hard ground contact in a nose high drift to the rear. Contributing to the IP's misinterpretation of the right yaw were limited visual clues due to a poor FLIR imaging condition resulting from the weather and low ambient light.
12	C	This accident involved an aircraft conducting battle operations while in an out-of-ground effect (OGE) hover. The pilot did not remain focused outside of the aircraft, thereby allowing the aircraft to settle into the trees. The copilot/gunner did not assist in providing warning to avoid obstacles or unanticipated changes in altitude. The pilot was determined to be unfit for flight as he was extremely fatigued as well as stressed due to his additional duties as a training officer and having had to take an unannounced exam. The pilot also experienced several aggravating aircraft and mission problems including poor FLIR imagery. He had also only logged one hour of NVS in the previous 30 days. Flight hours for his unit had been reduced due to the inability of the annual funding program to support the cost of repair parts as well as a reduction in paid flight hour training periods. This resulted in aviators working and flying in a no-pay status to maintain minimums. The limited flight time, coupled with the aircraft reduction, resulted in a high volume of waivers and compromised proficiency, thereby creating the perception that failing to make flight minimums was acceptable.
14	B	This night accident involved an aircraft striking a tree during a multi-aircraft terrain flight operation under visual flight rules (VFR) conditions. The flight was conducted under poor FLIR conditions (four days of rain) and the crew was heavily loaded with flight and mission tasks. Enemy radar was painting the aircraft, further adding to the workload of the crew. While hovering in a tight mountain ravine with variable winds and hovering NOE, the pilot failed to detect the aircraft drift and allowed the main rotor blades to make contact with the tree. The poor PNVS/ FLIR visual cues prevented the crew from detecting the trees (due to a lack of depth perception by PNVS/TADS and blooming). Problems also occurred with the hover hold box that required the pilot to remove his hand from the collective and divert his eyes inside the aircraft.

16	A	This dawn accident occurred during a night multi-aircraft flight in decreasing weather conditions. The flight leader modified the original flight plan of a 500-foot AGL as weather conditions deteriorated to continue the flight altitudes as low as 120 feet above ground level (AGL) while trying to maintain visual contact with the ground. The pilot of Chalk 7, while monitoring decreasing weather conditions and maintaining distance and clearance from Chalk 6, compromised Chalk 6's airspace, and Chalk 6 flew over Chalk 7. As a result, Chalk 7 struck high-tension wires as the pilot initiated a descent to a selected immediate landing area to ensure safe separation from Chalk 6. During this time, the PC was troubleshooting the FLIR and provided no assistance to the pilot. After taking over the controls, the PC became disoriented and thought he was in a right turn, but the aircraft turned left approximately 180 degrees from the initial wire heading and struck the same set of high tension wires ¾ mile south of the initial strike. The pilot did not provide assistance to the PC. The crew experienced a high level of anxiety due to the near midair collision and later wire strikes.
17	A	The night accident occurred during an attempted landing under marginal FLIR conditions, the pilot and IP failed to coordinate their actions. The IP in the front seat using the TADS/FLIR system did not request the assistance of the pilot in the backseat with the PNVS. The pilot was focusing inside of the aircraft, and failed to provide clearance assistance to the pilot under marginal FLIR conditions. Neither pilot noted any obstacles. The IP initiated a descent into 60-foot trees and the aircraft was destroyed.
19	C	This night flight accident occurred during a multi-ship night battle drill. While attempting to acquire targets in a battle position, the PC failed to maintain a stabilized hover and allowed the aircraft to descend into trees. The PC was distracted to his left while attempting to visually acquire his wingman. Poor PNVS image quality and a 15-knot tailwind added to the distraction and increased pilot workload. The PC lost situational awareness and the copilot was focused on acquiring targets.